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RESEARCH OF THE POSSIBILITY OF USING THERMOELECTRIC ELEMENTS (TEE) IN WELLS WITH LOW GEOTHERMAL GRADIENT

Об'єктом дослідження є свердловини з низьким температурним градієнтом менше 2–2,5 °С на 100 м (регіони Татарії, Башкирії, Удмуртії і т. д.). При вивченні компонування пристрою для утилізації геотермальної енергії використовувався метод системного аналізу. А в ході дослідження пристрою штангового глибинного насоса (ПШГН) і пристрою електровідцентрового насоса (ПЕЦН) використовувався метод порівняльного аналізу.

У роботі обговорюється питання про можливість економії енергоресурсів при експлуатації нафтових родовищ, що знаходяться в регіонах з невисоким геотермічним потенціалом об'єктів розробки. Розглядається спосіб вирішення проблеми як варіант комплексного використання не тільки петротермальної енергії надр, але також і гідрокінетичної енергії пластових вод. Показано, що утилізація низькотемпературної геотермальної енергії за рахунок її поєднання з утилізацією гідрокінетичної енергії води, що нагнітається через систему ППТ (підтримання пластового тиску), економічно вигідно. Це пов'язано з тим, що запропонований в роботі метод має ряд особливостей, зокрема, експлуатаційні (реагуючі) свердловини обладнуються на гирлі термоелектрогенераторів, що перетворюють теплову енергію пластового флюїду в електричну. Застосування подібних пристроїв дозволить знизити витрати електроенергії для живлення електроприводу ГНО (глибинне насосне обладнання) та інших споживачів електроенергії на свердловині. Електроенергія, що виробляється термоелектричними модулями постійного струму, підсумовується з усіх термоелектричних перетворювачів. Отримана енергія спрямовується по лінії на живлення телесистеми АСУ-ТП (автоматизована система управління технологічним процесом). Завдяки цьому забезпечується можливість отримання електричної енергії з низькотемпературних свердловин. У порівнянні з аналогічними відомими класичними методами, коли газовий фактор продукції, що видобувається, є досить високим (≥80–100 м^3/т), то практикується використання попутного газу для живлення електрогазотурбінних генераторів, що виробляють електроживлення для ГНО безпосередньо на експлуатаційній свердловині. Проте такий спосіб утилізації попутного газу на пізній стадії розробки є економічно неприйнятним, так як в цьому випадку він є вкрай низьким для його реалізації.

Ключові слова: *петротермальна енергія, гідрокінетична енергія, електрична енергія, теплова енергія, пластовий флюїд, комплексна утилізація.*

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1. Introduction

Utilization of petrothermal energy, as an unconventional and practically inexhaustible natural source of thermal energy, which, under certain conditions, can be converted into electric energy, has received increasing attention in many countries in recent years [1–3]. However, as practice has shown, the development of this type of energy, its efficient utilization with conversion to electrical energy, depends on many factors. The most significant factor is the range of reservoir temperature at the bottom of the wells [4, 5]. The researchers in [6] found that the profitability of the conversion of thermal energy of the subsoil is directly proportional to their temperature and inversely proportional to their depth. The geothermal gradient has a significant impact on the economic efficiency of the process of its disposal [7].

Researchers of this work are primarily interested in the problem of thermal energy utilization in regions with low geothermal potential (2–2.5 °C/100 m, regions of Tataria, Bashkiria, Udmurtia, etc.). Calculations showed [8] that with an average depth of production wells in this region up to 2200 m, the maximum temperature at the bottom is not more than 45–50 °C. And transportation of formation fluid to the surface from this depth allows to get no more than 30–35 °C, taking into account losses, which is clearly not enough to generate a sufficiently high electrical power. Therefore, the study of wells with a low geothermal gradient is relevant.

Thus, *the objects of research are* wells located in the regions of Bashkiria, Tataria, Udmurtia, etc., where the geothermal gradient does not exceed 2–2.5 °C per 100 m. And *the aim of research* is choose of a technology that allows to use the potential of low temperature wells.

2. Methods of research

The next methods are used in this research:
- a method of system analysis when studying the layout of a device for the utilization of geothermal energy;
- a method of comparative analysis in the study of the device of a sucker rod pumping unit (SRPU) and the device of an electric centrifugal pumping unit (ECPU).

3. Research results and discussion

As a way to solve the problem, let's offer a comprehensive solution by using not only the petrothermal energy of the subsoil, but also the hydrokinetic energy of the formation water.

It is known [9] that for pumping up to the surface of reservoir fluid during the operation of oil and gas wells at the final stage of development, when the reservoir pressure is lower than hydrostatic, deep-pumping equipment (DPE) is widely used.

Since, as a rule, the profitability of the operation of oil and gas wells at the final stage of development is low, oil producing companies widely practice measures that save energy DPE consumption. These include, first of all, the use of electric drives with frequency-controlled control, which allow to change the DPE capacity, depending on the change in the productivity of the exploited formations. Also, in order to save power consumption, it is practiced to use the regime of periodic operation of DPE at the time of day when the tariffs for paying for electricity are the lowest.

In cases where the gas factor of the produced products is sufficiently high (≥80–100 m^3/t), the use of associated gas is used to power electric gas and turbine generators that generate power for DPE directly at the production well. However, this method of utilization of associated gas at a late stage of development is not economically feasible, since in this case it is extremely low for its implementation.

As for the first two of these methods of saving energy, it is possible to say that:
- variable frequency drive is a rather expensive equipment with a long payback period;
- DPE use at the time of day when electricity tariffs are the lowest does not always justify itself economically. This is due to the high probability of a decrease in the rate of production extraction during the time of day, when tariffs are higher.

For more reliable energy savings, regardless of the time of day and the rate of production extraction and the gas factor, let's propose to equip the injection line of the focal injection well with a device. The device will consist of a hydroturbine electric generator utilizing the kinetic energy of produced water.

At the same time, production (reactive) wells are equipped at the wellhead with thermoelectric generators that convert the thermal energy of the formation fluid into electrical energy. The use of such devices will reduce the cost of electricity for powering the electric drive DPE and other consumers of electricity in the well.

Let's consider the layout of equipment for the utilization of kinetic and thermal energy contained in the fluid, both transported into the reservoir, and taken from it. Let's consider the layout using the example of a five-point operational cell, which is the main component of the development system for most oil fields (Fig. 1) [10, 11].

The five-point production cell includes four production wells 1 located at the corners of an equilateral quadrangle and an injection (focal) well 2 located in its center. The power supply and control of the DPE (SRPU, ECPU are not shown in Fig. 1) is carried out using the control cabinet 3, which is supplied with power via a power industrial line 4 (380 V). Water injected into the reservoir is fed to injection well 2 through a water conduit 5 from a cluster pump station (not shown in Fig. 1). The product (oil) extracted through production wells 1 is diverted using a prefabricated manifold 6. The mouth of the injection well 2 is equipped with a hydroelectric turbine 7 through which fluid is pumped through the water conduit 5 into the injection well 2.

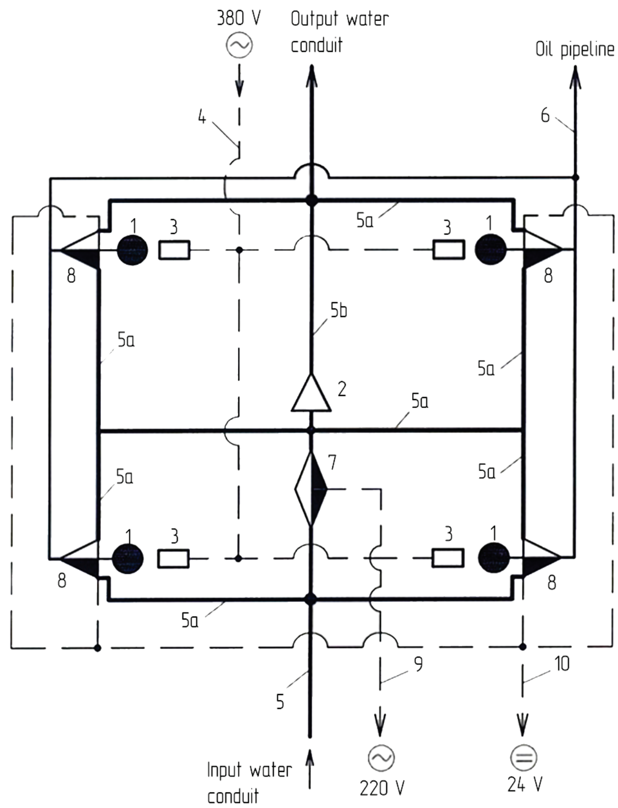

Fig. 1. The scheme of equipping the five-point production cell with equipment for the utilization of geothermal and hydrokinetic energy: 1 – production wells; 2 – injection well; 3 – DPE control cabinet; 4 – power line ~380 V; 5 – water conduit; 6 – prefabricated oil pipeline; 7 – hydroelectric turbine; 8 – thermoelectric modules; 9 – power line ~220 V; 10 – power line = 24 V

The mouth of production wells 1, in turn, is equipped with thermoelectric modules 8 containing heat exchangers (not shown in Fig. 1) through which the formation fluid coming from well 1 has a temperature above ground temperature. And on the other hand, they receive water from the reservoir pressure maintenance (RPM) system, supplied through special groundwater conduits of smaller diameter *5a*.

Electricity generated by a hydroelectric turbine with a voltage of up to 220 V is discharged through a power line 9 and through a transformer (not shown in Fig. 1) enters the industrial field network. And the electricity generated by thermoelectric modules 8 with voltage up to 24 V DC is summed from all thermoelectric converters 8.

The received energy is sent via line 10 to the power supply of the ASU-TP telesystem (automated process control system).

The proposed device for the comprehensive utilization of kinetic and thermal energy generated during the operation of a separate production cell works as follows (Fig. 1). The power supply of the DPE (not shown in Fig. 1) located in production wells 1 is carried out along the main power line 4 through the appropriate control cabinets 3. Water is injected into the reservoir through the focal well 2, into which it is supplied via the input line 5b to the next field cell (not shown in Fig. 1). At the mouth of the focal well 2 in the inlet water conduit 5, a hydroelectric turbine 7 is mounted, which is driven by kinetic energy of formation water moving through the conduit 5. Hydroelectric turbine 7 converts it into electrical energy of alternating current voltage up to 220 V, which is diverted from it through a power line 9 for subsequent consumption.

Thermoelectric current sources 8 are mounted on flow lines 6 of each production well 1. Current sources 8 convert the temperature difference between the formation fluid produced from well 1 and the water pumped into the focal well 2.

Electricity generated by each thermoelectric converter 8 in the form of a direct current voltage of up to 24 V is summed up using a power line 10 and sent for subsequent consumption to the ACS-TP telesystem.

4. Conclusions

It is shown that the direct utilization of low-temperature geothermal energy in oil-producing regions that are at a late stage of development by converting it into electrical energy is not economically viable. It is revealed that it is possible to increase the economic profitability of the utilization of low-temperature geothermal energy due to its combination with the utilization of the hydrokinetic energy of the water pumped through the RPM system. It is also found that the utilization of low-temperature geothermal energy can be carried out using thermoelectric elements (TEE). TEEs are installed on the flow line of production wells located near the injection well. The process of utilization of hydrokinetic energy can be carried out using a hydroelectric turbine installed inside the discharge line (water conduit).

The research results will be useful to oil producers as a solution to the issue of energy efficiency in the industry itself.

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